II. REGIONAL CHARACTERISTICS

A. ENVIRONMENTAL SETTING

1. Central and Northern Rocky Mountains

The Rocky Mountain region from northern Colorado to northern Montana encompasses a wide variety of landscapes and ecosystems. Geology, soils, aquatic systems, vegetation, and fauna are highly variable at both large and small spatial scales due to the complex mountainous topography of this region. The Rocky Mountains are rugged glaciated mountains with many peaks up to 4,500 m in elevation. Mountainous topography is generally highly dissected with intervening valleys and plateaus. Geology is spectacularly varied with a great diversity of igneous, metamorphic, and sedimentary bedrock of various ages. Glacial till is found in many locations as a result of various glacial advances during the Pleistocene. The presence of glaciers in many high mountain valleys and cirques attests to the geomorphically dynamic landscapes of the Rockies.

Soils in the Rocky Mountains are diverse with respect to topography, parent material, vegetation, climate, and time of formation. Many different soil orders are found, with inceptisols, entisols, alfisols, spodosols, aridisols and mollisols being most common. Because of the influence of gravity on steep slopes, colluvium is the most common surficial component of soils at most locations in mountains. Alluvium is also common in river valleys. It is difficult to generalize about the nutrient status and biogeochemical cycling properties of soils in the Rockies. These factors, in conjunction with analyses of potential impacts of air pollutants, should generally be assessed on a watershed basis.

The climate of the southern and central Rockies is considered to be a semiarid steppe regime in which there is considerable variation in precipitation with altitude. Total precipitation is moderate but greater than in the plains regions to the west and east. Foothill regions annually receive only 25 to 50 cm of rainfall, while higher elevations may receive as much as 100 cm. In the higher mountains, a major portion of annual precipitation is snow. Climate is strongly affected by prevailing winds, resulting in generally wetter western slopes and drier eastern slopes. Average annual temperatures range from 2 to 7ºC, with higher temperatures in lower valleys (Bailey 1980).

The climate of the northern Rockies is considerably colder; the average temperature of the coldest month is often lower than 0ºC and the warmest month is lower than 22ºC. Annual precipitation ranges from 50 to 100 cm, with much of it falling as snow. Summers generally are dry because prevailing westerly winds during this season transport relatively dry air masses from the Pacific Northwest (Bailey 1980).

The vegetation of the Rocky Mountains is dominated by coniferous forest but overall is quite diverse: each of the national parks in the Rocky Mountains contains over 1,000 vascular plant species and a wide variety of lichens, bryophytes, and fungi. The abundance and distribution of plant species vary at different spatial scales. The most obvious pattern of variation is associated with elevation, as mediated by differences in precipitation, temperature, and soils.

Some tree species are found throughout the Rocky Mountains. For example, ponderosa pine (*Pinus ponderosa*) is common on drier, low-elevation sites from ROMO to GLAC. Douglas-fir (*Pseudotsuga menziesii*) is common at lower elevations and is often mixed with other coniferous species. Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) are common species in subalpine forest ecosystems. Lodgepole pine (*Pinus contorta*) is often associated with fire disturbance. Quaking aspen (*Populus tremuloides*) is also associated with disturbance (fire, rockslides, and avalanches) as well as meadow margins, while other *Populus* species typically occur in riparian zones. A wide variety of grasses, forbs, and shrubs are found above treeline and in lower-elevation meadows. There are also many areas of bedrock and talus where little or no vegetation occurs.

With the exception of high elevation areas and most of the national park lands, most of the forests in the Rocky Mountains have been subjected to logging over the past 100 years. The majority of low elevation forests, particularly ponderosa pine forests, had been logged by the 1920s. Nearly all grasslands, including lower-elevation prairies and higher-elevation meadows have been grazed by domestic livestock; this includes many national park lands prior to their establishment as parks. The effect of these land use practices can still be seen throughout Rocky Mountain landscapes and provides a context for considering other potential environmental changes in the future.

Fire is an important disturbance at various spatial and temporal scales in all Rocky Mountain ecosystems. The impacts of fire are especially prominent at YELL, where fires of various intensity burned 500,000 hectares in 1988. However, the natural fire frequency is generally lower in some habitats than it was during the past century, primarily due to fire exclusion and altered ignition sources. As a result, some forest stands may have higher stem densities than they had a century ago. Similarly, some grasslands may have increased densities of shrubs and different combinations of grass and forb species (also affected by grazing). This may or may not reflect an "unnatural" condition in some situations but should be considered when assessing the vigor and productivity of ecosystems, particularly with respect to other stressors.

2. Northern Great Plains

The Great Plains region of western North Dakota and South Dakota is characterized by rolling plains and tablelands of moderate relief. They fall within a broad region that slopes gradually eastward down from the foothills of the Rocky Mountains. The highest elevations are found in the Black Hills of western South Dakota, with Harney Peak being the highest point (2,200 m).

This region is geomorphically diverse with relatively old geological formations free of glacial influences. Sedimentary rocks of a wide variety of ages dominate, although metamorphic and igneous rocks are also found in abundance. The Black Hills (where WICA is located) contain all three rock types, and the geologic map of this area contains 21 distinct mapping units (Darton 1951). Badlands of North Dakota in the vicinity of THRO and of South Dakota in the vicinity of BADL are comprised of a range of sedimentary materials including surficial clays that are eroded by active stream channels and ephemeral streams.

Soils of the northern Great Plains are diverse in terms of depth and amount of development. Inceptisols, entisols, and alfisols are found in the Black Hills, while mollisols are common in areas dominated by grasses. Entisols are also common in areas dominated by alluvium. A significant amount of badland landscape consists of areas generally not classified as soil because of lack of profile development and vegetation. Soils in grassland and alluvial areas generally have high base cation content. Calcification and salinization occur in some soils.

The climate is semiarid continental in which maximum precipitation occurs in summer, although total moisture supply is low and evaporation generally exceeds precipitation. Average annual temperature is 8ºC in much of the region. Winters are cold and dry, and summers are warm to hot. Annual precipitation is 35 to 45 cm at lower elevation plains locations and approximately 75 cm in the Black Hills (Froiland and Weedon 1990). With prevailing winds from the west, air masses reaching the northern Great Plains tend to have little moisture remaining after passing over the Rocky Mountains. The Black Hills further reduce precipitation to the east.

One of the most common tree species in the southern part of this region is ponderosa pine. This is the dominant tree in much of the Black Hills. It is also the most ozone-sensitive conifer in western North America. White spruce (*Picea glauca*) is also widely distributed at higher elevations and in cooler drainages of the Black Hills. Rocky Mountain juniper (*Juniperus scopulorum*) is the most widespread conifer at lower elevations in the Black Hills and elsewhere in the western Dakotas. Aspen is found on disturbed sites associated with coniferous forest and in riparian habitats. A variety of hardwoods are found in riparian areas and drainages, including plains cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), box elder (*Acer negundo*), and willows (*Salix* spp.).

Much of the lower elevation of the northern Great Plains is covered by mixed-grass prairie or shortgrass prairie. These grasslands are comprised of a diversity of grass, shrub, and forb species, with tallgrass and bunchgrass species generally more common on microsites with higher soil moisture. The dominant grassland species include wheatgrass (*Agropyron* spp.), needlegrass (*Stipa* spp.), grama (*Bouteloua* spp.), prairie junegrass (*Koeleria pyramidata*), and buffalo grass (*Buchloe dactyloides*). Various species of sagebrush (*Artemisia* spp.) and currant (*Ribes* spp.) are the most common shrub species mixed with different grassland types.

Nearly all of the northern Great Plains has been greatly disturbed by human activities. Forested areas - primarily the Black Hills - were extensively logged during the past century. Grasslands have been extensively grazed, including on national park lands until they were given protected status. Fire is an important source of ecological disturbance throughout the northern Great Plains, although fire frequency is now lower in some habitats than in the past few centuries due to fire exclusion and altered ignition sources. In the absence of fire, some forest stands have relatively high stem densities, particularly in the understory. Some grasslands may have previously burned every few years due to human- and lightning-caused ignitions. Fire exclusion and reduced human ignitions have probably encouraged a reduction in fire-adapted bunchgrass species and an increase in shrub species at some sites. In savanna areas (e.g., at WICA), ponderosa pine can encroach on prairie in the absence of fire. The past history of land use and disturbance must be considered when assessing the potential impacts of air pollutants and other stressors.

B. REGIONAL AIR QUALITY

The Rocky Mountain and northern Great Plains states are sparsely populated compared to Eastern states. Wyoming is the least populated state in the nation, and by the year 2000 the population is expected to reach only 522,000 inhabitants (Table II-1). The Dakotas and Montana each have fewer than a million people and expect moderate increases in population over the next 30 years. There are few large urban areas in Wyoming, Montana, and the Dakotas, and none qualify as metropolitan areas (larger than one million people). Colorado is the most populated of the Rocky Mountain states with a metropolitan area (Denver) and several smaller urban areas, Boulder, Colorado Springs and Fort Collins. The Front Range area of Colorado is currently experiencing a growth boom with urban and suburban development expanding at a rapid pace.

Utah lies to the west of the Rocky Mountains and is experiencing rapid growth in the Salt Lake City/Ogden region. Urban development is the largest source of VOC and NO_x emissions and these pollutants can be transported several hundred kilometers. Consequently air quality in southwestern Wyoming and in the vicinity of GRTE and YELL are potentially impacted by emissions from Salt Lake City; continued population growth could exacerbate these impacts.

Population growth in Idaho is expected to remain moderate (Table II-1). Air quality in Idaho is threatened more by growing industrial emissions than from urban development. Power plants, oil refineries and chemical plants are major sources of pollutant emissions in Idaho.

Most of the population growth in the Rocky Mountain and northern Great Plains regions is occurring near urban centers. While most of the national parks included in this report are remote from urban areas (ROMO is an exception; Figure II-1), regional transport of pollutants from urban areas to wildland areas may pose a threat to the air quality of the parks.

Figure II-1. National parks and major cities of the Rocky Mountain and northern Great Plains regions.

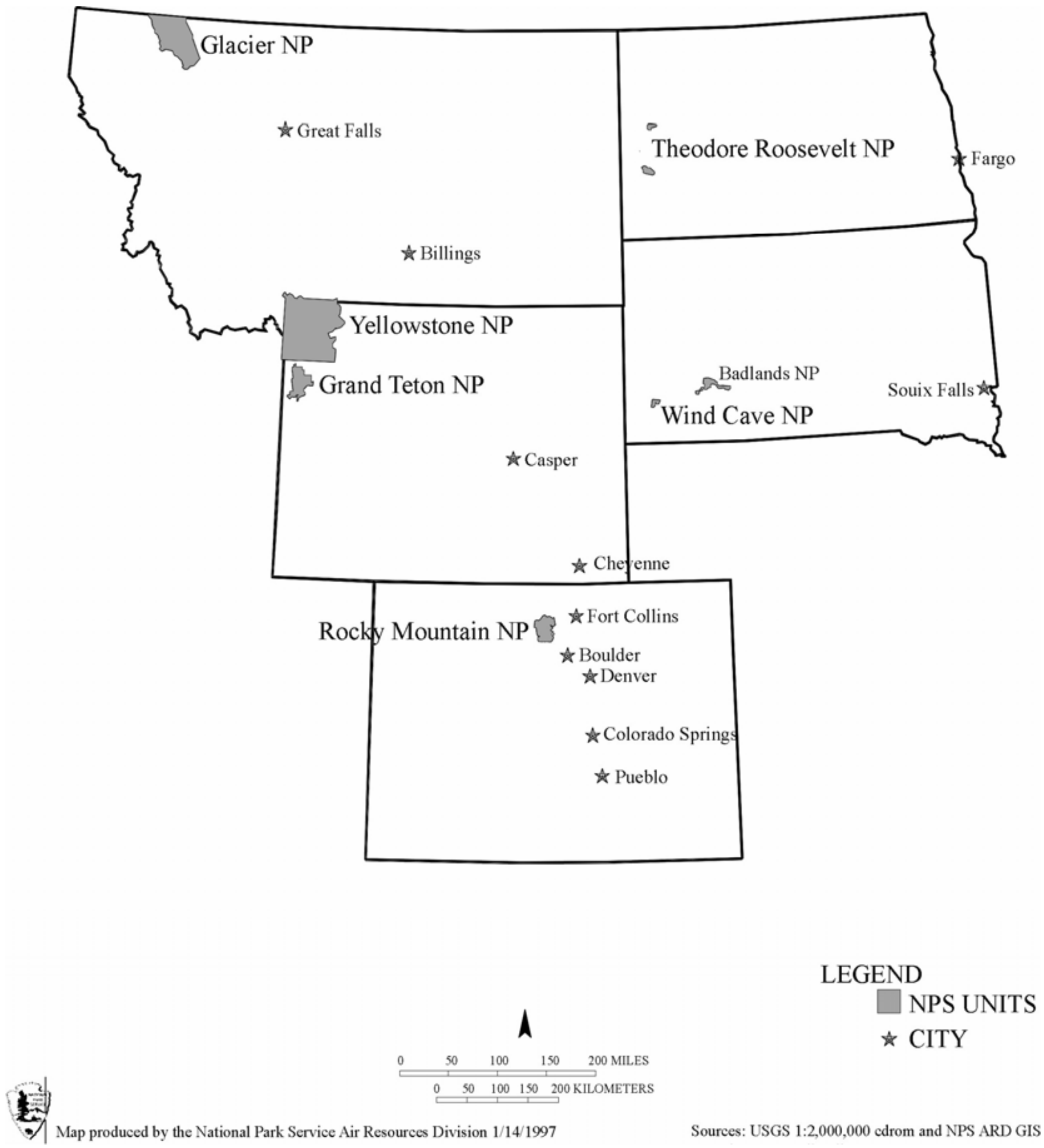

Table II-1. Projected population growth in Rocky Mountain and Northern Great Plains states. (Source: U.S. Department of Commerce 1990)			
	1990	2000	2020
Colorado	3,294,394	4,059,000	4,871,000
Montana	799,065	920,000	1,071,000
N. Dakota	638,800	643,000	719,000
S. Dakota	696,000	770,000	863,000
Idaho	1,012,000	1,056,00	1,097,00
Utah	1,722,850	2,148,00	2,749,00
Wyoming	453,588	522,000	658,000

Air quality data are summarized in this section on a state-by-state basis, because state agencies are responsible for administering air quality programs. A regional assessment of deposition and air quality can be found at the end of this section and park-specific summaries can be found within each park's section.

Gaseous pollutant monitoring and meteorological sites for each state in the Rocky Mountains and northern Great Plains are illustrated in US EPA's AIRS (Atmospheric Information Retrieval Systems) maps (Figures II-2 to II-6). Monitoring stations for SO_2, NO_2, and ozone are mostly located in or near urban areas, and consequently there is limited information on pollutant distribution to wilderness and rural areas. The NPS and USDA Forest Service maintain and operate monitoring sites in some wildland areas. Meteorological sites are scattered across most states, however they are generally placed near communities or towns. Wyoming has most of its meteorological sites in the eastern portion of the state where the majority of the population resides.

Categories of SO_2, NO_x and VOC emissions for the Rocky Mountain and Northern Great Plains states are listed in Tables II-2, II-3 and II-4. Annual emissions for Utah and Idaho are included because air quality in western portions of Wyoming and Montana are probably influenced by emissions from these states. Colorado and Utah have the highest total NO_x emission levels, mainly from fossil fuel combustion by electric power utilities and on-road vehicles. Colorado has the highest VOC levels, mainly from vehicles and industrial solvents. Areas in Colorado downwind of NO_x and VOC sources may be at risk for ozone pollution. Colorado, Wyoming and North Dakota all have annual SO_2 emissions exceeding 100,000 tons/year. In these states, electric utilities are the major sources of SO_2, followed by industrial fuel combustion (including oil and gas refining) and mining operations.

Figure II-2. Air quality monitoring and meteorological sites for Colorado. Data from U.S. EPA's Atmospheric Information Retrieval Systems (AIRS).

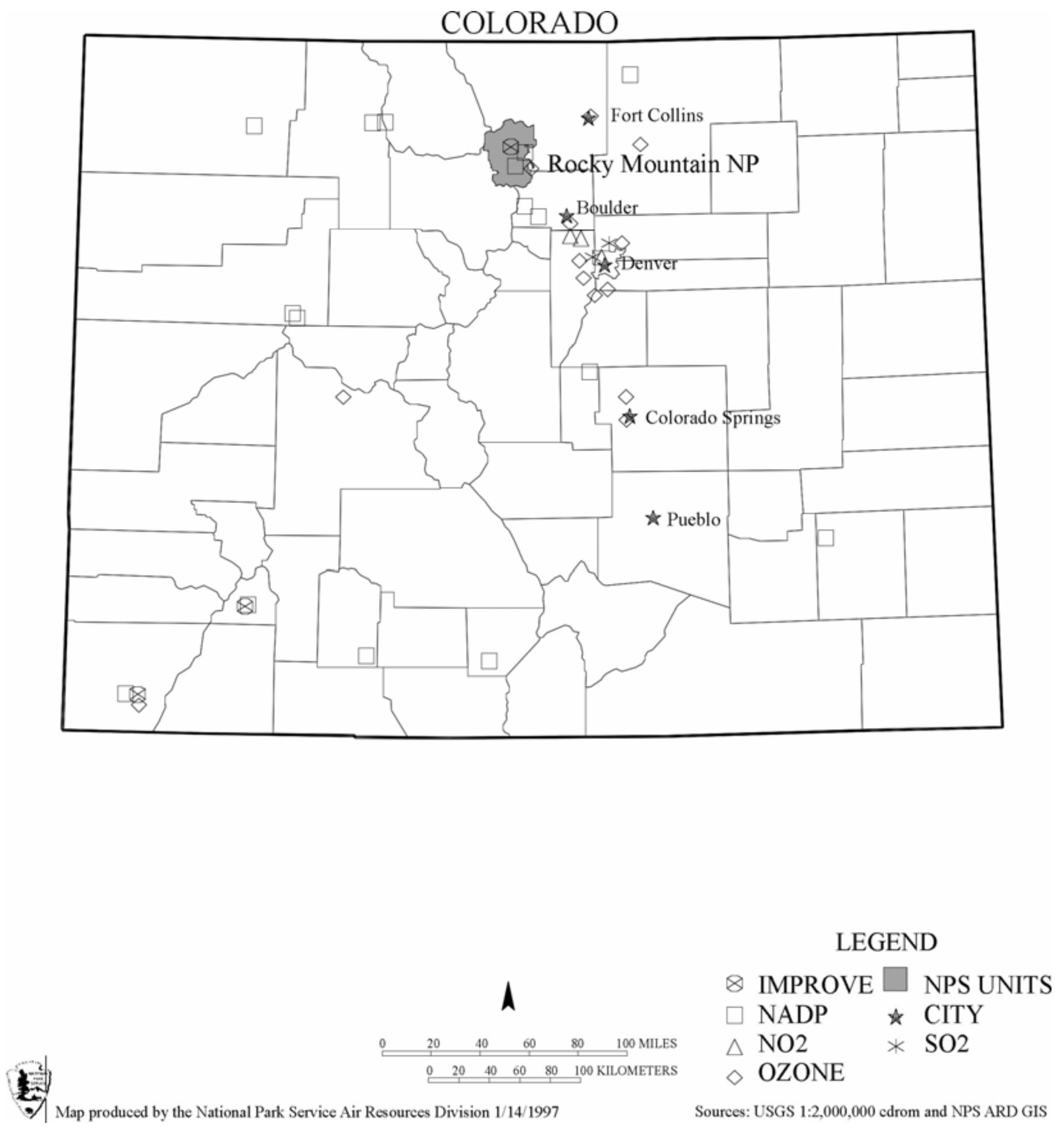

Figure II-3. Air quality monitoring and meteorological sites for Wyoming. Data from U.S. EPA's Atmospheric Information Retrieval Systems (AIRS).

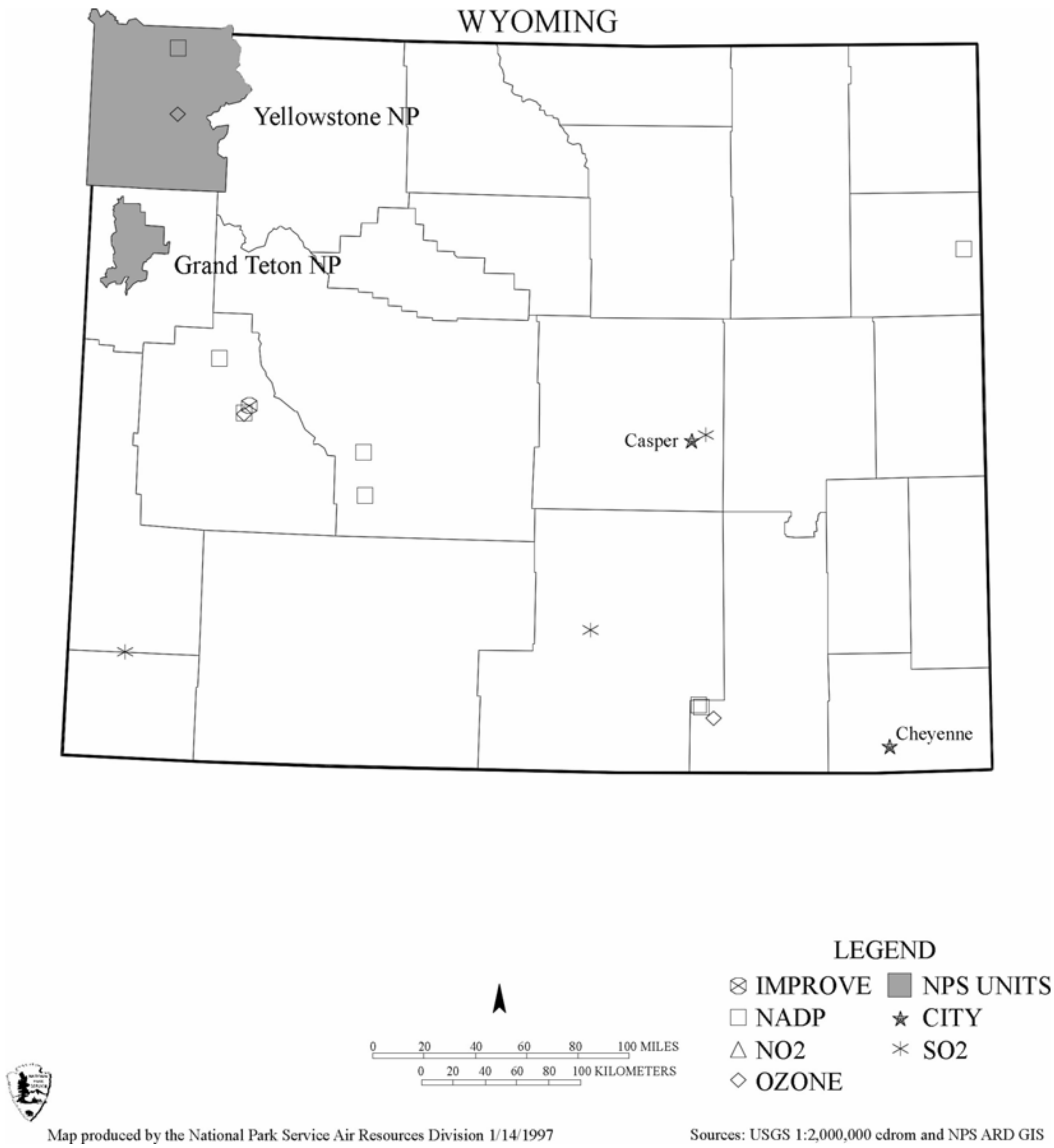

Figure II-4. Air quality monitoring and meteorological sites for Montana. Data from U.S. EPA's Atmospheric Information Retrieval Systems (AIRS).

Figure II-5. Air quality monitoring and meteorological sites for North Dakota. Data from U.S. EPA's Atmospheric Information Retrieval Systems (AIRS).

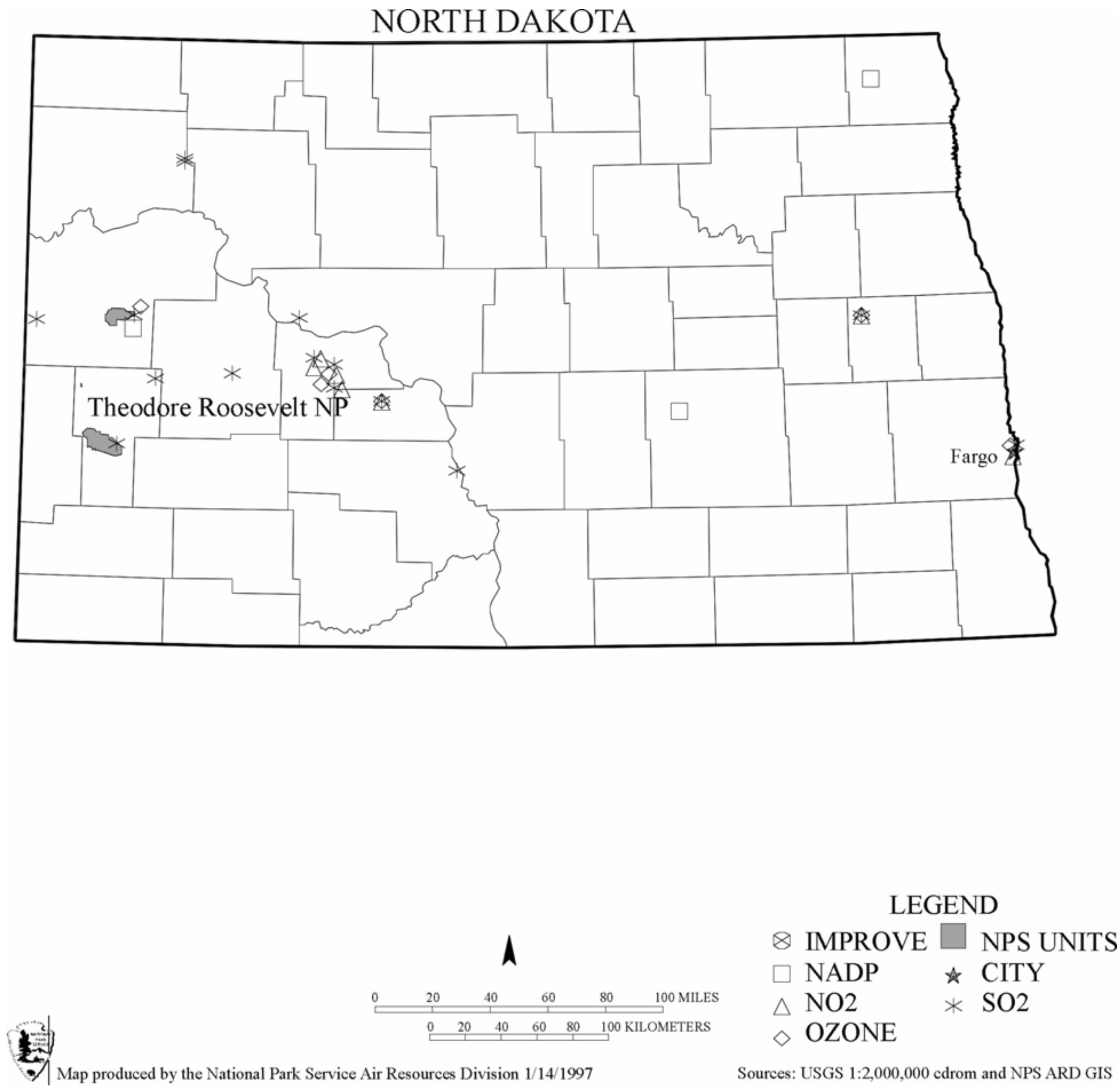

Figure II-6. Air quality monitoring and meteorological sites for South Dakota. Data from U.S. EPA's Atmospheric Information Retrieval Systems (AIRS).

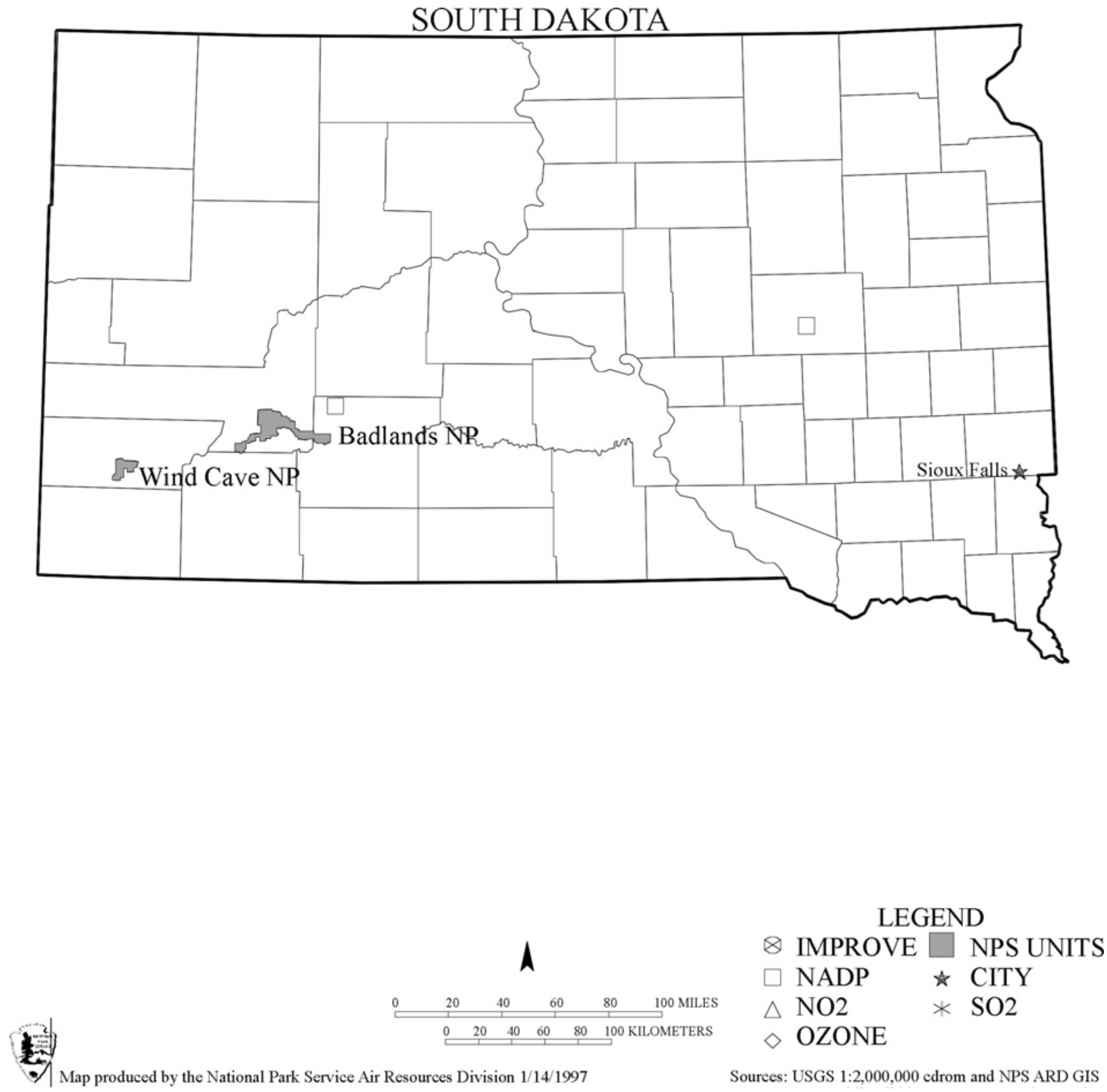

Table II-2. Annual emissions of SO_2 for Rocky Mountain and northern Great Plains states in 1994 (1000 short					
	Fuel Combustion Electric Utility	Fuel Combustion Industrial	Metals Processing	Fuel Combustion Other	Chemical Alliec
Colorado	88	6	0	3	0
Idaho	0	8	0	3	17
Montana	22	17	28	1	3
North Dakota	144	56	0	3	8
South Dakota	33	3	0	1	0
Utah	34	22	12	6	0
Wyoming	78	32	2	2	9
Total	399	144	42	19	37

[a] waste disposal, recycling, on-road vehicles, non-road sources and miscellaneous sources

Table II-3. Annual emissions of NO_x for Rocky Mountain and northern Great Plains states in 1994 (1000					
	Fuel Combustion Electric Utility	On-Road Vehicles	Fuel Combustion Industrial	Non-Road Sources	Fuel Comb Othe
Colorado	131	108	36	54	14
Idaho	0	43	12	15	2
Montana	66	34	13	29	2
North Dakota	124	24	20	14	2
South Dakota	22	30	3	6	2
Utah	105	58	30	28	6
Wyoming	173	27	67	24	2
Total	621	324	181	170	30

[a] includes industrial processes, waste disposal, recycling and miscellaneous sources

Table II-4. Annual emissions of VOCs for Rocky Mountain and northern Great Plains states in 1994 (100
1995)

	Solvent Utilization	On-Road Vehicles	Waste Recycling	Non-Road Sources	Storage and Transport
Colorado	73	94	5	35	21
Idaho	23	32	2	11	11
Montana	20	24	2	9	11
North Dakota	33	18	3	6	11
South Dakota	31	22	2	8	11
Utah	36	55	4	17	15
Wyoming	9	19	1	5	8
Total	225	264	19	91	88

[a] includes solid waste disposal, wildfires, miscellaneous sources

Emissions of SO_2 from point sources for 1996 are shown in Figure II-7. Montana, Idaho and Utah have numerous point sources with high emissions of SO_2, but most are located greater than 200 km from a national park. Colorado, North Dakota, and South Dakota have numerous SO_2 point sources (although many are too small to be regulated) near park boundaries, posing a potential threat to park resources. SO_2 emissions may affect resources in ROMO due to the proximity of numerous sources in the Denver area and Yampa Valley west of the park. Despite its low population, Wyoming has a large number of SO_2 point sources scattered throughout the state, with several located 100 km east of YELL. Prevailing winds from the southwest may protect the park from the impact of these neighboring emissions sources. In general, YELL and GRTE are remote from upwind urban and industrial development and therefore experience excellent air quality. However, eastern Wyoming has several point sources within 100 km of the Black Hills, posing a potential threat to air quality at WICA due to prevailing wind patterns.

NO_x emissions from point sources are presented in Figure II-8. The distribution of sources is similar to that of SO_2 sources. Wyoming, Colorado, North Dakota and South Dakota have numerous sources of NO_x within 100 km of a park boundary. In Montana, Idaho and Utah, most point sources are not in proximity to a park.

1. Emission Trends and Monitoring Data

Air quality monitoring in Rocky Mountain and northern Great Plains National Parks is summarized in Table II-5. The time series of data for various air quality components varies greatly within and among parks. However, even short-term measurement periods provide a basis for estimating pollutant deposition within the parks. Interpretation of these measurements can be supplemented in some cases by data from adjacent sites (e.g., NADP data) and by monitoring data previously collected in the parks (e.g., passive ozone sampler data).

a. <u>Montana</u>

Agriculture, wood-burning stoves, coal mines, industrial activity and unpaved roads are the major sources of particulates in Montana (Martin et al. 1995). Several areas have been in non-attainment for particulate matter (PM) following the Clean Air Act amendments (1977). Efforts to bring these areas into compliance with State Implementation Plans (SIP) have been marginally successful.

SO_2 is of concern in areas near point sources. Coal-fired power plants are located in Billings and Colstrip. Petroleum refineries are located in both Billings and Great Falls. Various other SO_2-emitting facilities are also located in Billings. Colstrip, Columbia Falls, Missoula, Great Falls and Billings are sites of major VOC point sources (>100 tons/yr). The state's largest point sources for NO_x are located in Missoula, Billings and Great Falls. Emissions from Missoula and Columbia Falls

Figure II-7. 1996 SO_2 point sources for the Rocky Mountain and northern Great Plains regions (provided by NPS-ARD).

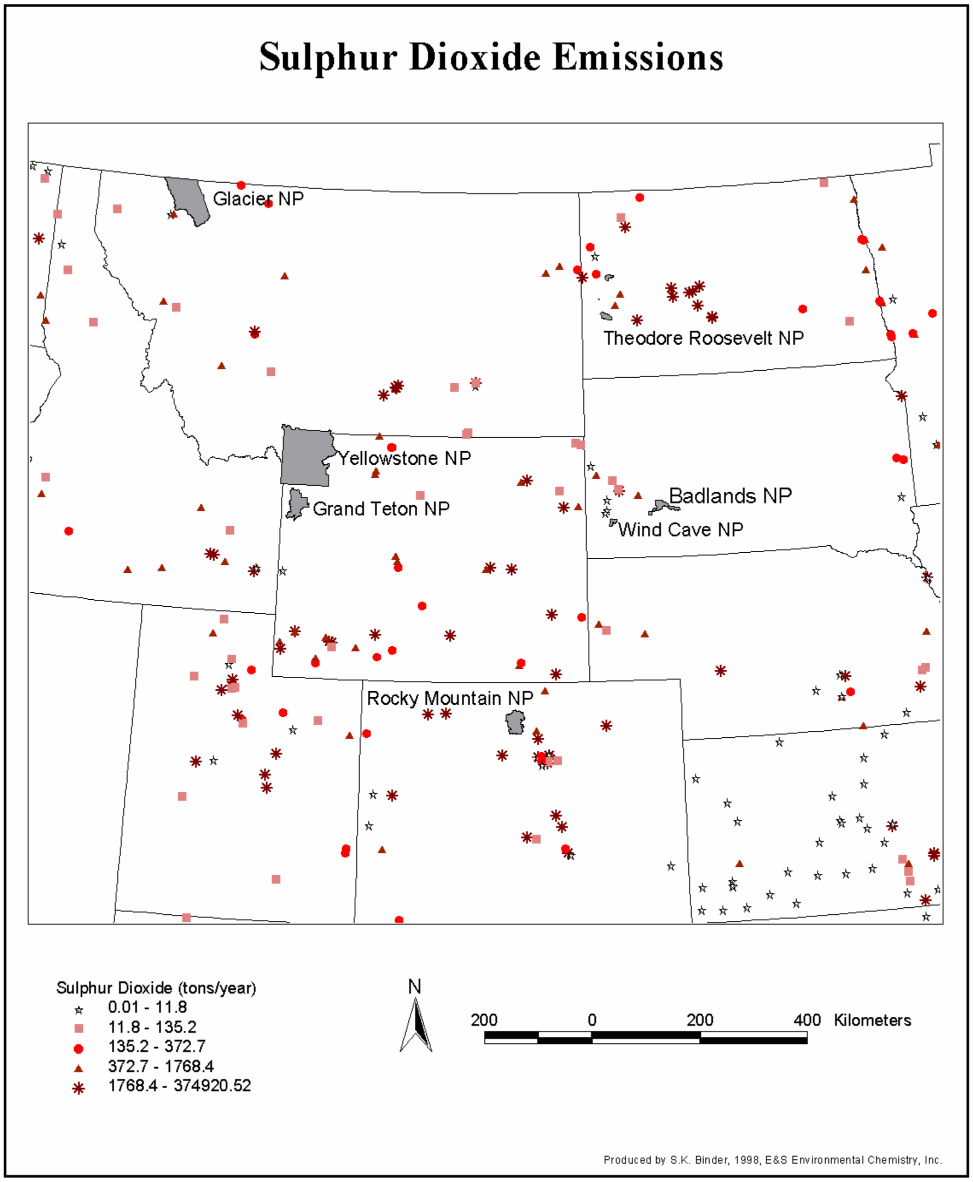

Figure II-8. 1996 NO_x point sources for the Rocky Mountain and northern Great Plains regions (provided by NPS-ARD).

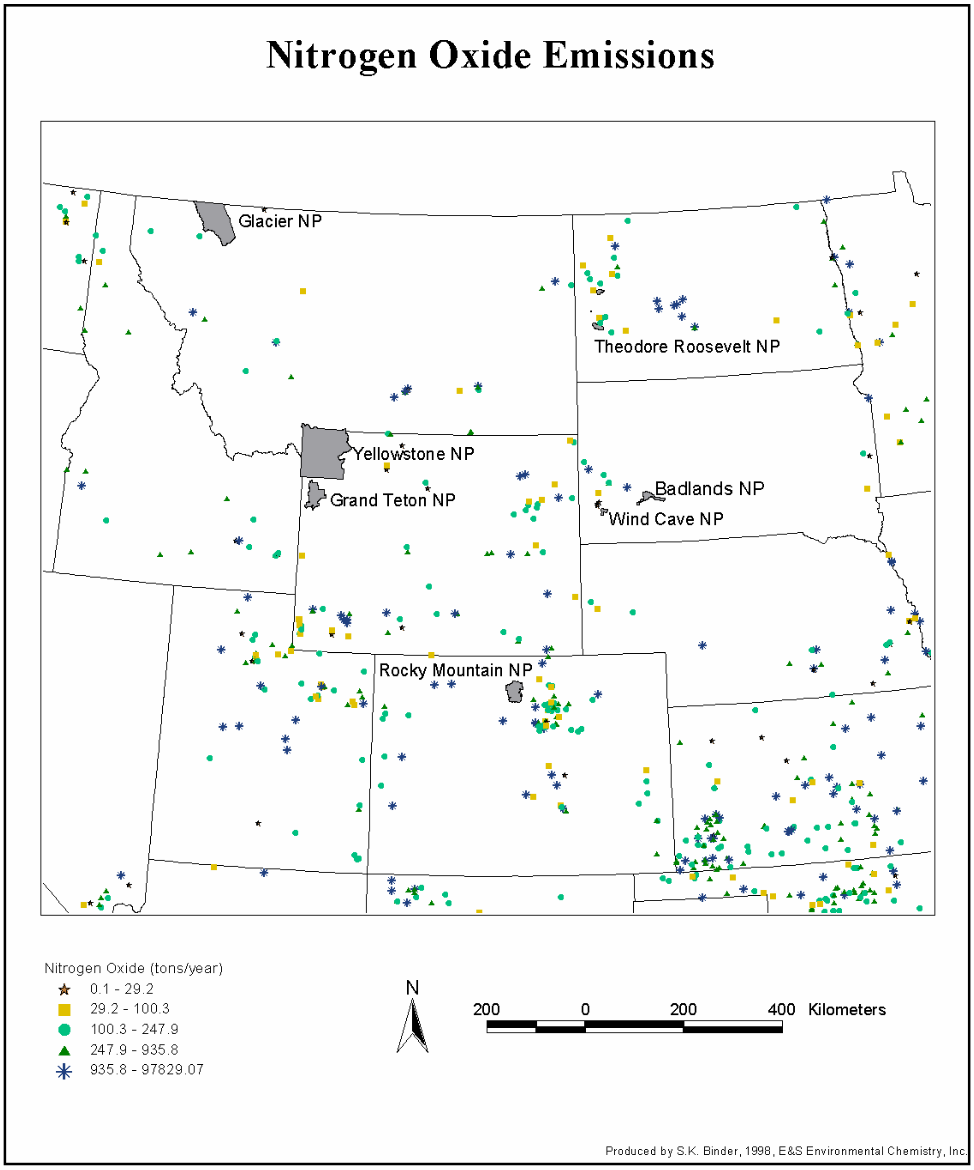

Table II-5. Current air quality monitoring in Rocky Mountain and northern Great Plains National Parks.							
Park	Ozone	IMPROVE	SO_2	NADP	NDDN	Fluoride	H_2S
BADL	**	X		X[a]			
GLAC	X	X	X	X	X	X	
GRTE	**						
ROMO	X **	X	X	X	X		
THRO	X		X	X			X
WICA	**						
YELL	X	X	X	X	X		

[a] located approximately 20 km northeast of BADL
** indicates data have been collected with passive ozone samplers

may also have some impact on air quality in GLAC during periods of southerly winds (prevailing winds are from the west/southwest).

Lead pollution is a concern in East Helena, where the primary source of pollution is the ASARCO lead smelter. East Helena has been in non-attainment for lead since 1978, and the current SIP was expected to bring the area into compliance by 1997 (Martin et al. 1995). Fluoride, a byproduct of aluminum manufacturing, has been a local pollution problem for the Columbia Falls area (near GLAC) since 1957 when the Anaconda Aluminum Company began operating. Maximum emissions of fluoride reached 1,500 tons/year by 1969 but have been reduced to 180 tons/year since 1981.

b. Colorado

NO_x, VOC, SO_2, and particulates are emissions of concern in Colorado. Major sources of NO_x are fuel combustion associated with electric utilities and motor vehicles (Table II-3). VOC sources include vehicles, industry, and solvent utilization. Sulfur dioxide emissions are mainly from fuel combustion associated with electric utilities. Although emissions of NO_x, VOC, and SO_2 have declined between 1975 and 1994 and there have been no NAAQS exceedences of NO_2 in Colorado, projected population growth in the state could result in future degradation of air quality.

Ozone is a pollutant of concern in the Denver area to the east of the Rocky Mountains. The mountains restrict airflow, resulting in frequent occurrences of haze and stagnant air due to inversions caused by persistent high pressure systems in the region. During such inversions, ozone and ozone precursors build up and can result in high ozone levels at ROMO. In 1993, ambient ozone levels in ROMO, 100 km northwest of Denver, exceeded the hourly maximum NAAQS (pre-

1997 standard) on one occasion.

c. Wyoming

NO_x and VOC emissions and particulate matter from oil and gas facilities, mining, power generation, and other industrial sources are pollutants of concern in Wyoming. Electric utility and fossil fuel burning associated with industry are the dominant sources of NO_x and SO_2 (Tables II-2 and II-3) in the state. There is also some oil and gas development on Bureau of Land Management (BLM) lands in southwestern Wyoming and in the Shoshone and Bridger-Teton National Forests. Proposed new industrial sources in addition to thousands of small sources (< 250 tons/year) may result in increased NO_x and VOCs in the future.

The Wyoming Department of Environmental Quality monitored SO_2 in several locations throughout the state between 1972 and 1985, but levels were not high enough to warrant further monitoring. Nitrogen dioxide was monitored between 1975 and 1985, but also discontinued. Lead has been monitored since 1977 at three sites: Casper, Cheyenne and Rock Springs. Lead is monitored every 5 to 6 years, and the most recent data are from 1989. Lead levels in Wyoming have not exceeded the NAAQS since monitoring began. The state does not monitor ozone, and the only continuous ozone analyzer in Wyoming is operated and maintained by the NPS in YELL.

d. South Dakota

Coal burning power plants, wood stoves, unpaved roads, and grass fires are the major sources of PM-10 in South Dakota. The Department of Environment and Natural Resources currently monitors PM-10 at eight sites in three counties. The state does not currently monitor SO_2, NO_2, NO_x, or ozone, although an inventory of emissions by point sources has been compiled in an AIRS data base. South Dakota point sources of emissions of NO_x, VOC, and SO_2 are summarized in Tables II-2, II-3 and II-4. Most point sources for these pollutants are located in the eastern portion of the state.

e. North Dakota

Monitoring by the North Dakota State Department of Health indicates that air quality is generally very good in North Dakota. The population is sparse and there are no large metropolitan areas. There have been no exceedences of state standards for ozone or NO_2 since at least 1985. The major sources of pollution are associated with oil and gas production as well as coal-fired electrical generation. These sources are located in the western portion of the state, as are the Class I areas. The primary pollutants associated with these activities are SO_2 and H_2S. PSD Class I increments for SO_2 at THRO are being exceeded, although no effect on resources has been detected. Because oil and gas activities have the potential to increase in North Dakota, these increment exceedences will also likely increase unless they are mitigated. Most of the sources in the vicinity of THRO have emissions too low to be regulated, but the total of these many small sources could have significant impacts on resources that are sensitive to elevated S inputs.

f. Utah

Although Salt Lake City lies over 200 km to the southwest of Jackson Hole and the Teton Mountains, it may still affect the air quality in GRTE and YELL. Annual emissions of SO_2 and NO_x from Salt Lake City are relatively high. In 1994, emissions of SO_2 totaled 45,200 tons per year and NO_x emissions totaled 71,000 tons per year. Winds from the south and southwest may deliver these pollutants to the vicinity of the parks. However, there have been no studies on regional transport of pollutants from Salt Lake City to confirm this. The relatively high emissions from Salt Lake City are the largest component of total state emissions, although power plants at other locations (e.g., Bonanza) may produce emissions that affect GRTE and YELL. The largest component of NO_x and SO_2 emissions is from electric utilities.

g. Idaho

Idaho has no urban areas and there are currently no large point sources of NO_x, SO_2, or VOC within 200 km of GLAC, YELL or GRTE. Coal-fired power plants at the Idaho National Engineering Lab and a phosphate plant at Idaho Falls contribute some emissions to the overall state total. Industrial growth in the region is expected to expand and may result in increasing emissions that could be transported to the vicinity of the parks.

2. Regional Emission Patterns and Air Quality Issues

There is no single regional emission problem that strongly affects all national parks in the Rocky Mountains and northern Great Plains. Some parks are subject to deposition of pollutants from urban areas, some are affected by long-distance transport of pollutants from industrial facilities and electric utilities, and some are affected by local sources. Therefore, the quantity of emissions received and the potential threat to natural resources must be analyzed individually for each park. General patterns of emissions and air quality concerns are summarized briefly here and in more detail in sections on the individual parks.

There are serious concerns about air quality at ROMO because of elevated concentrations of ozone during the summer, a potential threat to vegetation, and increased levels of N deposition, a potential threat to terrestrial and aquatic systems. In addition sulfates and nitrates contribute to visibility impairment. Most of the emissions are from urban areas in the Front Range of the Rocky Mountains between Colorado Springs and Fort Collins and especially the Denver metropolitan area. Rapid population growth in this area poses an ongoing threat to air quality in the Front Range because of high VOC emissions which contribute to ozone formation, and because of high NO_x emissions and ammonium (NH_4^+) deposition which contribute to ozone formation and N deposition to terrestrial and aquatic systems. High emissions of NO_x from the Salt Lake City area of Utah may also contribute to the regional air quality that affects ROMO, although there are no data that clearly demonstrate this. Although pollution control measures are becoming increasingly strict in the Denver area, summertime ozone exposure and total N deposition will continue to be concerns at ROMO for the foreseeable future.

Emission threats to YELL and GRTE are relatively minor. Most deposition in this area is due to long-distance transport from sources to the west. Industrial and electric utility facilities in Idaho produce NO_x and VOCs that can contribute to ozone formation. The Salt Lake City, Utah, region to the southwest may also contribute ozone precursors to the YELL/GRTE region. Emissions data for Wyoming indicate that the state produces large quantities of NO_x and SO_2. Most of these emissions are from industrial and power-generation facilities to the east of YELL and GRTE; only relatively uncommon easterly winds would transport these pollutants into the parks. However, oil and gas developments on Bureau of Land Management (BLM) land in southwestern Wyoming have been proposed.

Industrial and electric-utility facilities in Idaho produce NO_x and VOCs that can contribute to ozone formation in GLAC. The Seattle-Tacoma-Vancouver area (and possibly Spokane) to the west may also contribute ozone precursors to the GLAC region, although the nature of this long-distance transport is unknown. Sources of NO_x and VOCs in Montana - most of which are to the east and south of GLAC - may contribute to degradation of the park's air quality only during periods of nonprevailing easterly and southerly winds. Emissions of fluoride from an industrial facility in Columbia Falls, Montana, have been a source of concern for many years, with potential acute and cumulative impacts on vegetation, but emissions have declined in recent years.

The northern Great Plains parks are also remote from cities and large emission sources, although there are some emissions that could potentially threaten park resources. At THRO, hundreds of small oil wells adjacent to the park emit both SO_2 and H_2S. While the emissions per well may not be large, the combined emissions of all the wells are substantial. Furthermore, some wells are very close to the park boundary where there could be acute impacts to vegetation on a local basis. Additional SO_2, NO_x, and VOCs are potentially transported from industrial and electric-utility facilities in Montana. The cumulative and acute effects of the S point sources are the greatest concern at THRO. The development of additional coal-fired power plants in eastern Wyoming would increase emissions transported to THRO.

Small quantities of emissions from the Rapid City, South Dakota, area may reach WICA, but of greater importance are regional-scale sources from eastern Montana and eastern Wyoming. Prevailing westerly winds transport NO_x, SO_2, and VOCs eastward over the Black Hills region and WICA, providing sufficient precursors for ozone formation during the summer when it is sunny and warm. The development of additional coal-fired power plants in eastern Wyoming would increase emissions transported to WICA.

Regional-scale emissions of NO_x and SO_2 from industrial and electric-utility facilities in eastern Wyoming and western South Dakota are the greatest concern at BADL. Annual emissions of NO_x in Wyoming are particularly high, and although VOCs are relatively low, they may influence the airshed of BADL sufficiently to provide precursors for ozone formation during warm, dry summer weather. The development of additional coal-fired power plants or other point sources in eastern Wyoming would be expected to increase emissions transported to BADL.